

# Species diversity and stability of natural secondary communities with different cutting intensities after ten years

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**Abstract:** Species diversity and stability of natural secondary communities in different layers with different cutting intensities 10 years later were investigated by calculating Margalef Richness index ( $R$ ), Shannon-Wiener diversity index ( $H$ ), Simpson diversity index ( $P$ ), and Pielou Evenness index ( $J$ ). Results show that the values of  $R$ ,  $H$  and  $P$  among different layers are listed in a decreasing order: the shrub layer > the arbor layer > the herb layer, all the three indices values reach the maximum under medium selective cutting intensity after 10 years. The  $J$  value of the shrub layer shows a concave parabolic change with the increase in cutting intensity; it shows a linear increase for the arbor layer, whereas the  $J$  value of the herb layer shows an opposite change pattern. The values of  $R$  at different cutting intensities had high significant difference, but other indices had not significant difference. The stability of communities at different cutting intensities after 10 years is non-cutting > low selective cutting intensity > medium selective cutting intensity > high selective cutting intensity > extra-high intensity > clear cutting. The stability of communities at different cutting intensities after 10 years shows that the greater cutting intensities, the worse the stability is.

**Keywords:** community stability; cutting intensity; natural secondary forest; species diversity

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## Introduction

Forest cutting can cause large fluctuations of species diversity and stability. How to maintain the species diversity and stability in the process of community reinsertion after cutting is an issue to be considered (Lei and Tang 2000; Zhou et al. 2007). In recent years, some works on this topics were done from different angles (Margalef 1975; Zhu et al. 1997; Tilman 2000; Zhou et al. 2004; Qiu and Chen 2005; Jin et al. 2006; Tai et al. 2009; Indra et al. 2010), however, the species diversity and stability of natural secondary forest in mid-subtropical zone seldom have been studied under long-term tracking investigation and research after different cutting intensities (Zhou et al. 2007). Selective cutting can make full use of tree growth potential and forest productivity, increase species diversity and improve resistance against forest diseases. It is favorable for the rational circulation of nutriment. It can reduce the brokenness intensity of forest, improve the protection efficiency of forest and form the harmonious view. As selective cutting is in accordance with the natural law, it was received more and more attention by ecologists, biologists, forestry scholars and logging scholars (Qiu and Chen 2005; Zhou et al. 2007). In the present study, species diversity and stability of natural secondary communities in different layers with different cutting intensities ten years later were studied. The aim was to offer scientific basis for the diversity protection of forest plant and establish the studied foundation of community stability.

## Materials and methods

### Study site

This study was conducted in the Dayuan Forest Harvesting and Silviculture Farm, Jian'ou Prefecture, Fujian Province, southern China (117°58'45"–118°57'11"E, 26°38'54"–27°20'26"N), located in southeast of the Wuyi Mountains and northwest of the Jiufeng Mountains. Evergreen broad-leaved forests are naturally

distributed in this area. The elevation of the site ranges from 535 to 755 m and slopes are in the range of 15°–35°. This area has a subtropical, maritime monsoon climate. The mean annual temperature is 15–17°C, and annual precipitation is 1 890 mm. The total amount of annual evaporation is 1 327.3–1 605.4 mm and average relative humidity is 85%. The soil type is yellowish red soil derived from gneissic and granitic rocks.

#### Plot setting

In March 1996, 12 plots (20 m × 20 m) were set up for selective cutting with different intensities in the virgin forest, and four comparative plots were set up for non-cutting (two) and clear cutting (two). These plots had similar stand conditions, which may minimize the effect of the natural condition on each kind of selection cutting. The 12 plots were grouped into four blocks based on similarities in topography and tree density allowing for three replications of each of four levels of cutting operation, randomly assigned to each block.

Four different intensities of selective cutting were carried out in the designated plots, which were low intensity (13.0%), medium intensity (29.1%), high intensity (45.8%) and extra-high intensity (67.1%). Diameter, varieties, density and growing situation of trees were considered synthetically. *Pinus massoniana* and *Schima superba* were mainly felled under low intensity cutting. *P. massoniana* was mainly felled under middle cutting intensity. *P. massoniana* and *Castanopsis carlesii* were mainly felled under high and over-high intensity cutting. Cutting operation was in accordance with the rules of single tree selective cutting, i.e., felling with chain saw, bucking at the stump and skidding by manpower. Settings were cleared by removing all branches whose diameters were more than 5 cm for utilization. All other slash was left in the setting. When the cutting operation was finished on November 1996, the residual stands were closed off for natural regeneration. There was no evidence of disturbance before a third investigation was held in July 2006. It takes evergreen broad-leaved forest as the core now.

In July 2006, the 12 plots of different selective cutting intensities and three plots of non-clear cutting and clear cutting were investigated again in the natural secondary forest after ten years. Vegetations in these plots were investigated by using the regular methods of community ecology. Every plot was divided into 16 bordering quadrants of 5 m × 5 m size. For every quadrant, tree species, height (length for lianas), diameter at breast height (DBH) or diameter at ground for shrubs and herbs were recorded. Forest litters within plots were collected for further analysis, and soil sections were examined in every plot as well (Zhou et al. 2008). In the natural vegetation, the dominant species of the arbor layer are *Castanopsis eyrei*, *Castanopsis carlesii*, *Daphniphyllum oldhamii*, *Pinus massoniana* and *Schima superba* etc. The dominant species of shrub layer are *Adinandra millettii*, *Lithocarpus glaber*, *Engelhardtia fenzelii*, *Symplocos congesta*, *Eurya nitida* and *Raphiolepis indica* etc. The dominant species of herb layer are *Dicranopteris dichotoma*, *Smilax china*, *Woodwardia japonica*, *Hicriopteris chinensis*, *Gahnia tristis* etc. The situation of all plots before and after felling was described in

detail in our previous publications (Zhou et al. 2007; Zhou et al. 2008).

#### Calculation of species diversity

Marglef Richness index ( $R$ ), Shannon-Wiener diversity index ( $H$ ), Simpson diversity index ( $P$ ) and Pielou Evenness index ( $J$ ) were selected to calculate diversity and evenness of species by the following formula (Qiu and Chen 2005; Zhang et al. 2002).

$$R = (S - 1) / \ln N \quad (1)$$

$$H = - \sum_{i=1}^s (N_i / N) \ln(N_i / N) \quad (2)$$

$$P = 1 - \sum_{i=1}^s (N_i / N)^2 \quad (3)$$

$$J = H / \ln S \quad (4)$$

where,  $N$  is the total number of individuals of all the vegetation species of the community,  $N_i$  is the number of individuals of the species,  $i$  and  $S$  is the number of community species.

Based on respective calculation of the diversity of the shrub layer, the arbor layer, and the herb layer, all species diversity was calculated by the following formula.

$$D = W_1 D_1 + W_2 D_2 + W_3 D_3 \quad (5)$$

where  $D$  is the diversity of all species, the  $D_1$ ,  $D_2$  and  $D_3$  are the diversity indices of the shrub layer, the arbor layer, and the herb layer, respectively. The  $W_1$ ,  $W_2$  and  $W_3$  are the proportion coefficient of the shrub layer, the arbor layer, and the herb layer, respectively; their values are 0.5, 0.25, and 0.25, respectively (Zhang et al. 2002).

#### Calculation of species stability

According to the calculation of M. Godron, the ratio of the percentage of plant and accumulation of relative frequentness is 20/80, which is the steady point, and the more close to 20/80, the more stable is (Godron 1972; Zheng 2000).

## Results and analysis

#### Comparison of the species diversity

The values of  $R$ ,  $H$ , and  $P$  among different layers were in a decreasing order: the shrub layer > the arbor layer > the herb layer (Table 1). It showed convex parabolic change with the increase in cutting intensities. The values of  $R$ ,  $H$ , and  $P$  all reached the maximum under medium intensity selective cutting after ten years. Regularity of evenness index values was inconsistent.

Evenness index values of the shrub layer changed in the shape of concave parabola with the increase of cutting intensities, which reached the minimum with high intensity selective cutting. Evenness index values of the arbor layer increased in the shape of straight line with the increase of cutting intensities, in contrast, evenness index values of the herb layer showed an opposite change pattern. For all the species, the values of richness index and diversity index were the selective cutting>non-cutting>clear cutting, and showed convex parabolic change with the increase of cutting intensities. These values reached the maximum with the medium intensity selective cutting after 10 years, and the minimum with clear cutting 10 years later. However, evenness index values were opposite. The diversity indices of selective cutting were basically larger than that of non-cutting and clear cutting.

**Table 1. The diversity indices of communities in different layers under different cutting intensities after 10 years**

Layer	Cutting intensity	Marglef Richness index	Shannon-Wiener diversity index	Simpson diversity index	Pielou Evenness index
Arbor layer	Non-cutting	1.828	1.923	0.795	0.69
	LI	2.904	2.006	0.809	0.694
	MI	3.191	2.029	0.825	0.716
	HI	2.671	2.02	0.822	0.746
	OHI	2.493	1.996	0.817	0.756
Shrub layer	Clear cutting	1.001	1.786	0.803	0.859
	Non-cutting	6.252	3.165	0.932	0.909
	LI	7.333	3.17	0.938	0.843
	MI	8.11	3.232	0.942	0.83
	HI	7.628	3.169	0.933	0.823
Herb layer	OHI	7.257	3.168	0.932	0.861
	Clear cutting	6.439	3.164	0.928	0.876
	Non-cutting	0.361	0.693	0.5	1
	LI	0.69	0.904	0.563	0.902
	MI	1.276	1.339	0.692	0.832
All species	HI	1.168	1.092	0.584	0.788
	OHI	0.965	0.989	0.541	0.78
	Clear cutting	0.805	0.824	0.486	0.75
	Non-cutting	2.567	1.926	0.756	0.822
	LI	3.459	2.022	0.78	0.783
	MI	3.942	2.157	0.817	0.774
	HI	3.535	2.075	0.79	0.776
	OHI	3.302	2.037	0.781	0.788
	Clear cutting	2.312	1.89	0.755	0.836

LI: Low selective cutting intensity (13.0%), MI: Medium selective cutting intensity (29.1%), HI: High selective cutting intensity (45.8%), OHI: Over-high selective cutting intensity (67.1%).

Difference test showed that the values of *R*, *H* and *P* had high significant difference among different layers. The *J* had significant difference among different layers. The *R* had high significant difference among different cutting intensities, but other indices did not have significant difference (Table 2).

**Table 2. Difference test of communities in different layers with different cutting intensities 10 years latter**

Index	Layer			Cutting intensity		
	F	P-value	F crit	F	P-value	F crit
R	470.903	0.000**	4.103	7.117	0.004**	3.326
H	536.902	0.000**	4.103	2.413	0.111	3.326
P	142.269	0.000**	4.103	1.700	0.222	3.326
J	4.122	0.049*	4.103	0.480	0.784	3.326

\*\*: High significant difference, \*: Significant difference. *R*, Marglef Richness index; *H*, Shannon-Wiener diversity index; *P*, Simpson diversity index; *J*, Pielou Evenness index.

#### Analyses on variability of diversity index

Among different cutting intensities, variability of these diversity indices of both arbor layer and shrub layer was  $R>J>H>P$ , but herb layer was  $R>H>P>J$  (Table 3). Among different layers, variability of these diversity indices of different cutting intensities was  $R>H>P>J$  (Table 4).

**Table 3. Variation of plant species diversity in different layers among different cutting intensities**

Index	Arbor layer			Shrub layer			Herb layer		
	A	B	CV	A	B	CV	A	B	CV
R	2.348	0.804	0.342	7.170	0.708	0.099	0.878	0.334	0.381
H	1.960	0.093	0.048	3.178	0.027	0.008	0.974	0.225	0.231
P	0.812	0.012	0.014	0.934	0.005	0.005	0.561	0.074	0.132
J	0.744	0.063	0.084	0.857	0.032	0.037	0.842	0.094	0.111

A: Average, B: Standard deviation, CV: Coefficient of variation,  $CV=B/A$ . *R*, Marglef Richness index; *H*, Shannon-Wiener diversity index; *P*, Simpson diversity index; *J*, Pielou Evenness index.

**Table 4. Variation of species diversity among different layers under different cutting intensities 10 years later**

Index	Non-cutting			LI			MI		
	A	B	CV	A	B	CV	A	B	CV
R	2.814	3.067	1.090	3.642	3.382	0.929	4.192	3.525	0.841
H	1.927	1.236	0.641	2.027	1.133	0.559	2.200	0.958	0.435
P	0.742	0.221	0.297	0.770	0.191	0.247	0.820	0.125	0.153
J	0.866	0.159	0.184	0.813	0.107	0.132	0.793	0.066	0.084
Index	HI			OHI			Clear cutting		
	A	B	CV	A	B	CV	A	B	CV
R	3.822	3.380	0.884	3.572	3.282	0.919	2.748	3.198	1.164
H	2.094	1.040	0.497	2.051	1.091	0.532	1.925	1.176	0.611
P	0.780	0.178	0.229	0.763	0.201	0.263	0.739	0.228	0.308
J	0.799	0.055	0.069	0.784	0.030	0.039	0.828	0.068	0.083

A: Average, B: Standard deviation, CV: Coefficient of variation,  $CV=B/A$ . *R*, Marglef Richness index; *H*, Shannon-Wiener diversity index; *P*, Simpson diversity index; *J*, Pielou Evenness index.

#### Analyses on stability of communities

The stability of communities with different cutting intensities 10 years later was non-cutting>LI>MI>HI>OHI> clear cutting (Ta-

ble 5). Especially, the stability of community under low intensity selective cutting is close to non-cutting. It showed that the greater cutting intensities, the worse the stability was.

**Table 5. Results of stability for community with different cutting intensities after 10 years (Godron's method)**

Cutting intensity	Curve type	Relevant coefficient ( $R^2$ )	Coordinate of crossing point	Intensity of stability (%)
Non-cutting	$y=-0.0153x^2+2.3578x+10.587$	0.9818	31.0/69.0	86.27
LI	$y=-0.0129x^2+2.055x+17.527$	0.9712	31.1/68.9	86.14
MI	$y=-0.013x^2+2.1417x+11.649$	0.9906	32.5/67.5	84.39
HI	$y=-0.0108x^2+1.9248x+12.527$	0.9879	34.2/65.8	82.27
OHI	$y=-0.0123x^2+2.1181x+6.9843$	0.9936	34.5/65.5	81.90
Clear cutting	$y=-0.0084x^2+1.6892x+12.389$	0.9922	36.8/63.2	79.03

LI: Low selective cutting intensity (13.0%), MI: Medium selective cutting intensity (29.1%), HI: High selective cutting intensity (45.8%), OHI: Over-high selective cutting intensity (67.1%)

## Conclusion and discussion

In the present study, the values of richness index and diversity index were the selective cutting>non-cutting>clear cutting and showed convex parabolic change with the increase in cutting intensities, which reached the maximum with medium intensity selective cutting 10 years later and the minimum with clear cutting 10 years later. However, evenness index values were opposite. The results of difference inspection showed that the values of richness indices and diversity indices had high significant difference among different layers. Richness index values had high significant difference among different cutting intensities. Variability of these diversity indices was  $R>J>H>P$  for different layers and  $R>H>P>J$  for different cutting intensities. For the communities with different cutting intensities 10 years later, the greater cutting intensities, the worse the stability was.

Forest felling with different intensities have different influence on the stand structure and species diversity. The original communities are destroyed completely after clear cutting. The ecological environment has relative small changes after selective cutting, especially low and medium intensity. So, selective cutting management of natural secondary forest is reasonable. The selective cutting must be controlled in low or medium intensity. It is beneficial to keep and recover the original species. Reasonably selective cutting also has important significance for precious and rare species. The dynamic change of species diversity of natural forest community after different cutting intensity needs further research, multi-discipline and accumulation of time serial data (Zhou et al. 2004; Jin et al. 2006; Liu 2006; Zhou et al. 2007; Zhou et al. 2008). At the same time, the trees should be reasonably selected for suitable felling. The purposes are for improving the conditions of illumination, humidity, and transmittance in the forest, and also adjusting the composition

and structure of forest. It is beneficial to restoration and growth of undergrowth vegetation (Liu 2006). Natural forest community of different intensity ten years later in the Dayuan Forest Harvesting and Silviculture Farm is still in the dynamic change course. M. Godron can only offer the stable information or not, but can not prove its direction and trend performs (Zheng 2000). Therefore, the interreaction of species diversity and stability need further study in following years.

## References

- Godron M. 1972. Some aspects of heterogeneity in grasslands of Cantal. *Statistical Ecology*, **3**: 397–415.
- Indra PS, Mulualem T, Per CO. 2010. Changes in tree species diversity and dominance across a disturbance gradient in Nepalese Sal (*Shorea robusta* Gaertn. f.) forests. *Journal of Forestry Research*, **21**(1): 25–32
- Jin Yong-huan, Li Dun-qi, Jiang Hao-xiang, Liu Jun, Li Guang-hua. 2006. Changes in species diversity of natural secondary forests after selective cutting disturbance in Changbai Mountain. *Journal of Jilin Agricultural University*, **28**(1): 35–39.(in Chinese)
- Lei Xiangdong, Tang Shouzheng. 2000. Progress in quantitative studies on the forest management effects on community diversity. *Chinese Journal of Ecology*, **19**(3): 46–51.(in Chinese)
- Liu Yongchuan. 2006. Study of applications of selective cutting management techniques in natural forests. *Forest Engineering*, **22**(5):7–9, 18. (in Chinese)
- Margalef R. 1975. Diversity, stability and mutuality in natural ecosystems. In: Dobben W.H., LOWE-MCCONNELL R.H. (Eds) *Unifying Concepts in Ecology*. Wageningen: Centre for Agricultural Publishing and Documentation, 151–160.
- Qiu Renhui, Chen Han. 2005. Effects of selective cutting of different intensities on the tree layer structure and species diversity of evergreen broad-leaved forest. *Chinese Journal of Eco-Agriculture*, **13**(3): 158–161.(in Chinese)
- Tai Likun, Yu Xuebiao, Yang Zengjiang, Shi Zhongjie, Zhou Weiwei, Guo Junyu. 2009. The compare of the understory vegetation diversity and biomass of three types of forest. *Ecology and Environmental Sciences*, **18**(1): 237–242. (in Chinese)
- Tilman D. 2000. Causes, consequences and ethics of biodiversity. *Nature*, **405**: 208–211.
- Zhang Feng, Zhang Jingtun, Shangguang Tieliang. 2002. Plant diversity of forest community in Zhuweigou of Lishan Mountain Nature Reserve. *Acta Phytocologica Sinica*, **26**(S1): 46–51. (in Chinese)
- Zheng Yuanrun. 2000. Comparison of methods for studying stability of forest community. *Scientia Silvae Sinicae*, **36**(5): 28–32. (in Chinese)
- Zhou Xinnian, Wu Zhilong, Zheng Lifeng, Cai Ruitian, Luo Jizhang, Lin Haiming. 2008. Biomass and nutrient content of forest litter in natural forest of different intensity harvesting after ten years. *Scientia Silvae Sinicae*, **44**(10): 25–28. (in Chinese)
- Zhou Xinnian, Wu Zhilong, Zheng Lifeng, Deng Shengmei, Lin Haiming, Xu Shaohong. 2007. Research progress on forest selective cutting. *Journal of Mountain Science*, **25**(6): 629–636.(in Chinese)
- Zhou Zhichun, Xu Gaofu, Jin Guoqing, He Jianping. 2004. Growth of broad-leaved species and community restoration of secondary masson Pine forest after selective cutting. *Forest Research*, **17**(4): 420–426.(in Chinese)
- Zhu Jinmao, Jiang Zhilin, Jiang Wei, Zheng Qunrui, Jiang Xunqiang. 1997. The effects of human caused disturbance on species diversity of forest community in northern Fujian Province. *Biodiversity Science*, **5**(4): 24–31.(in Chinese)